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Intercropping of Isabgol (*Plantago ovata* L.) and Lentil as Influenced by Drought Stress

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Abstract: In search for sustainable agricultural methods for medicinal plants, a field experiment was conducted on isabgol-lentil mono and row intercropping, along with irrigation interval regimes (4, 7 and 14 days irrigation interval) at the agricultural experimental farm of Zabol University during 2009. The experiment design was split-plot randomized complete block design with four replicates. Main plot treatments were giving irrigation at 4, 7 and 14 days interval and subplot treatments consisted of (a) sole isabgol; (b) sole lentil; (c) 1:1 isabgol-lentil intercropping system; (d) 1:3 isabgol-lentil intercropping system; and (e) 3:1 isabgol-lentil intercropping system. The results of the experiment confirmed that drought induced by increasing irrigation interval significantly decreased the growth of both crops and total N concentration of isabgol plants. Results also showed that lentil suppressed biological and grain yield of intercropped isabgol, but the reduction in isabgol yield was compensated by lentil grain yield. Isabgol biological and grain yield was significantly different across cropping systems and the yields were as follows: sole isabgol (281), 1:3 isabgol-lentil (93), 1:1 isabgol-lentil (191) and 3:1 isabgol-lentil (230). Lentil biological and grain yields was also significantly different across the treatments and was sole lentil (1096), 1:3 isabgol-lentil (846), 1:1 isabgol-lentil (644) and 3:1 isabgol-lentil (318). Intercropping isabgol and lentil increased the productivity with LER of 1.10, 1.27 and 1.11 for 1:3 isabgol-lentil, 1:1 isabgol-lentil and 3:1 isabgol-lentil, respectively. In intercrops a significant reduction in LAI, CGR and also significant increase in leaf and tiller number per plant, plant height, spike length, spike number per plant, grain number per spike and 1000-grain weight of isabgol was observed over sole isabgol. These changes were proportional with row number of isabgol in intercropping. Significant interaction effect of cropping system by irrigation regimes on many cases of measured parameters showed intercropping protects plants from drought. Total concentration of N in isabgol were increased by intercropping, however cropping system by irrigation regimes interaction on N concentration was not significant. These findings suggest that intercropping isabgol-lentil at combination of 1:1 with 7-days irrigation interval may be recommended for yield advantage, more efficient utilization of resources and N concentration on hot and dry regions of South-East Iran.

Key words: Intercropping % Isabgol % Lentil % LER % Drought % N concentration

INTRODUCTION

In recent year's attention has focused on the diversified agricultural production systems for maximizing utilization of resources as compared to the monoculture cropping systems [1]. The improved use of resources results in greater total intercrop yields as compared to sole crops of the same species grown on the same area. This is due to differences in competitive ability for growth factor between intercrop attributes in time and space and improved of soil fertility through the addition of nitrogen (N) by biological N fixation and excretion from the attributes legume [2]. Intercropping is also expected to reduce risk of a single crop failure due to pest and disease incidence and increase food security [3].

Isabgol (*Plantago ovata* Forsk.) are annual species that have originated from arid and semi-arid zones and are used widely in traditional and industrial pharmacology [4]. It is reported grains and husks of isabgol are used widely in pharmacology as laxatives [4]. Interest in isabgol has risen primarily due to its use in high fiber breakfast cereals and from claims that it is effective in reducing cholesterol [5-8]. Monoculture of small and sensitive plants such as isabgol against unfavorable conditions impose the yield and quality damage caused by pests.

Lentil (*Lens culinaris*) is rich in protein and suited for animal feed as well as for human diet. Other positive effects of lentil are the symbiotic N fixation (SNF) ability supplying N for agricultural systems, improve soil structure, reduced pest and disease incidence and hormonal effects through rhizodeposition [9].

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Many studies have shown the advantage of non N fixing with N fixing for a series of food and feed crops [For example, wheat-pea [10], wheat-chickpea and wheat-lentil [11], scarlet eggplant (*Solanum aethiopicum* L.) - cowpea [12], peanut-maize [13], leek-celery [14], sorghum-soybean 1[5], barley-faba, barley-bean and barley-lupin [16]. However, to our knowledge, this is the first systematic study of the medicinal plants as isabgol intercropped with legume crops.

Drought is a significant limiting factor for agricultural productivity and generally inhibits plant growth trough reduced water absorption and nutrient uptake. Decreased water availability generally results in reduced growth and final yield in crop plants. However, plant species in a mixed cropping system may vary in their responses to growth under water stress because water availability is known to be spatially heterogeneous distributed in time and space [17, 11].

The objective of this study was to evaluate the influence of drought stress on the yield and yield attributes of isabgol-lentil row intercropping compared to respective sole crops at three level of water availability.

MATERIALS AND METHODS

Site Description: Field experiment was conducted in 2009 on agricultural experimental farm of Zabol University (61°29~ N, 31°2~E, 450 m a.s.l.), in south east of Iran. The experiment was established in a sandy loam soil [19% clay (<2 µm), 21% silt (2-20 µm), 41% fine sand (20-200 µm) and 21% coarse sand (200-2000 µm)], with pH 7.8, organic mater 0.11%, N-No_3 2.9 ppm, P (Olsen) 2.2 pp and K 156 ppm (0-30 cm depth).

The experimental site is located in warm and arid region with mean annual precipitation of 63 mm and annual mean long-term average temperature of 23°C. In the experimental year (2009) the annual precipitation and mean temperature were 98 mm and 20°C, respectively. These values differed considerable from the long-term average. The precipitation was above long-term average and mean temperature was below long-term average. The preceding crop was forage corn (*Zea mays* L.).

Experimental Layout: Seedbed preparation included ploughing, disk harrowing and cultivation. Lentil used in this experiment was the short season, called Lektille, while isabgol used was landrace of Iran. The experimental design for this study was a split-plot randomized complete block design with four replicates. Main plot treatments were giving irrigation at 4, 7 and 14 days interval, in each irrigation 50 mm water was applied through flooding. Subplot treatments consisted of (a) sole isabgol (40 isabgol plant m^{-2}); (b) sole lentil (40 lentil plant m^{-2}); (c) one row of isabgol alternating with one row of lentil, 1:1 isabgol-lentil intercropping system (20 isabgol and 20 lentil plant m^{-2}); (d) one row of isabgol alternating with three rows of lentil, 1:3 isabgol-lentil intercropping system (10 isabgol and 30 lentil plant m^{-2}); and (e) one row of lentil alternating with three rows of isabgol, 3:1 isabgol-lentil intercropping system (30 isabgol and 10 lentil plant m^{-2}); The treatments were laid out in 6*6 m plots and both crops at both monocropping and intercropping was sown at a spacing of 0.25 m between rows and 0.10 m within rows.

Seeds of Both Crops Were Sown by Hand: Sowing date for isabgol was 20 February 2009 and harvest date was 14 June 2009. Sowing date for lentil was 21 February and harvest date was 16 June 2009. Adjacent subplots were separated by a 0.5 m wide ridge and the main plots were separated by a 1.5 m wide ridge. All plots were given 100 kg P_2O_5 as triple super phosphate together with half of the N fertilizer before sowing uniformly broadcasted and plowed into 15 cm soil. The other half of N fertilizer were applied with irrigation approximately 30 DAP. During the growth period all plots were weeded manually. No serious incidence of insect or disease was observed and no pesticide or fungicide was applied to either crop.

Plant Sampling and Growth Analysis: At the end of growth period five isabgol plants or five lentil plants were sampled and plant height, number of leaf per plant and some yield attributes were recorded. Total N concentration in plant samples were estimated at the end of growth season following micro-Kjeldhal method.

At maturity, heads of isabgol and pods of lentil were harvested from each plot, sun dried for approximately 10 days to around 10% moisture content, threshed and weighed to determine grain yield. Total vegetative above-ground dry matter was determined by collecting all remaining above ground biomass from the same plots.

Both sole and intercropped isabgol were sampled for growth analysis at approximately 15-day interval between 20 DAP and harvest. The plant samples were oven-dried at 65°C for 72 h to a constant weight and dry weight was recorded. The leaf area index (LAI) was estimated as basis on specific leaf area (cm^2 g^{-1}) and total leaf DM production on a sub-sample of isabgol.

Crop Growth Rate (CGR), the increase in dry weight per unit ground area of crop in a unit time, was calculated as $(W_2-W_1)/(t_2-t_1)$, where W_1 and W_2 are dry weight at times t_1 and t_2, respectively and expressed as g m^{-2} per day.

Calculations and Statistics: The relative advantage of intercropping compared to sole culture was calculated for each proportion using Land Equivalent Ratio (LER). The LER was calculated according to:

$$\text{LER} = \frac{Y_{ii}}{Y_{si}} + \frac{Y_{il}}{Y_{sl}}$$

Where Y_{ii} and Y_{si} are the grain yields of intercrop and sole isabgol and Y_{il} and Y_{sl} are the grain yields of intercrop and sole lentil, respectively. An intercropping system exhibits a yield advantage if the effect of facilitation is greater than that of competition, i.e. if LER>1.0; conversely, a disadvantage is shown if LER<1.0 [18].

Data collected were subjected to the analysis of variance (ANOVA). Test of significance of the treatment difference was done on a basis of a *t*-test. The significant differences between treatments were compared with the critical difference at 5% level of probability.

RESULTS

Lentil: In general, lentil growth measured by plant height, leaf and sympodial number per plant and yield attributes (pod number per plant, grain number per pod and 100--grain weight) was greater in intercrops than monocrops (Table 1). Among intercropping systems, the highest values of most parameters were obtained at lentil plant grown at 3:1 isabgol-lentil intercropping system, whereas lowest values of these parameters were registered at 1:3 isabgol-lentil intercropping system.

On averaged across all cropping systems, lentil produced 42.8% higher biological yield in monoculture than intercropped lentil (Table 3). The grain yield of lentil was the highest in monocropped (1096 kg hG^{1}), followed by 1:3 isabgol-lentil intercropping system (846 kg hG^{1}), 1:1 isabgol-lentil intercropping system (644 kg hG^{1}) and 3:1 isabgol-lentil intercropping system (318 kg hG^{1}).

The lowest biological and grain yield in lentil was recorded in irrigation at 14 days interval (Table 3). The biological and grain yield with irrigation at 4 and 7 days interval were not different in intercropping systems, but were significantly (*P*#0.05) different in sole cropping (data not provided).

Isabgol

Growth: The CGR of isabgol was low at initial stage and attained its peak between 95 and 100 DAP (Fig. 1a). The apparent decrease of biomass during the period from 100 to the final harvest is related to the shedding of leaves. LAI followed a trend similar to CGR and increased exponentially during the first 52 DAP, before it leveled off and declined at the end of growth period (Fig. 1b).

Table 1: Effects of cropping systems and irrigation interval regimes on plant height, number of leaf and sympodial per plant and yield attributes of lentil

Treatment	Plant height (cm)	Number of leaves (palntG^{1})	Number of sympodial (palntG^{1})	Number of pods (palntG^{1})	Number of grains (podG^{1})	100-grain weight (g)
Cropping systems						
Sole lentil	42.1b*	26.7c	6.9b	1.5c	1.8a	38d
1:3 isabgol-lentil	42.4a	27.2b	7.4b	1.7b	1.9a	48b
1:1 isabgol-lentil	42.2a	30.7a	8.4a	1.9a	1.8a	52a
3:1 isabgol-lentil	42.7a	28.0b	7.1b	1.8b	1.9a	41c
Irrigation interval regimes						
4 days	47.6a	34.3a	8.3a	1.8a	1.9a	46.8a
7 days	41.4b	28.2b	7.6b	1.7a	1.8a	44.4b
14 days	32.5c	22c	6.2c	1.7a	1.8a	43.1b

* Values followed by the same letter within the same columns do not differ significantly at *P* = 5% according to DMRT

Table 2: Effects of cropping systems and irrigation interval regimes on plant height, number of leaf and tiller per plant and yield attributes of isabgol

Treatment	Plant height (cm)	Number of leaf (palntG^{1})	Number of tiller (palntG^{1})	Spike length (mm)	Number of spike (palntG^{1})	Number of grain (spikeG^{1})	1000-grain weight (g)
Cropping systems							
Sole isabgol	16.9b*	37.0c	3.8c	1.9b	6.7b	71.7c	1.4a
1:3 isabgol-lentil	17.2a	39.1b	4.0b	2.0a	6.9a	74.7b	1.4a
1:1 isabgol-lentil	17.1ab	41.3a	4.2a	2.1a	7.0a	77.2a	1.5a
3:1 isabgol-lentil	18.0a	38.9b	4.0b	2.1a	6.9a	74.6b	1.4a
Irrigation interval regimes							
4 days	19.0a	44.1a	4.0a	2.1a	7.7a	80.6a	1.4a
7 days	16.9b	40.0b	4.1a	2.0a	6.5b	76.8b	1.5a
14 days	16.0b	33.1c	3.9a	2.0a	6.3b	66.3c	1.4a

* Values followed by the same letter within the same columns do not differ significantly at *P* = 5% according to DMRT

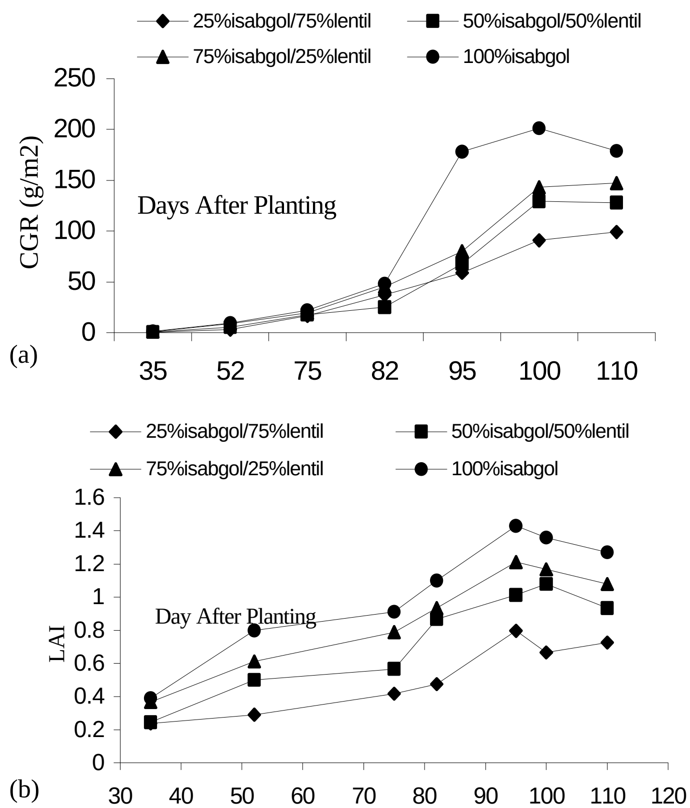

Fig. 1: Effects of cropping systems on (a) CGR and (b) LAI of isabgol plants during growth season

CGR and LAI of isabgol plants were reduced in intercropping systems than monocropping. The magnitude of reduction increased with decreasing row number of isabgol in intercropping. Except the first three samples of early season, monocropped isabgol recorded significantly (*P*#0.05) greater CGR at all stages over intercropped isabgol with all combination (Fig. 1a). A significant reduction in LAI was observed in all isabgol-lentil intercropping systems over sole isabgol (Fig. 1b). However, one row of lentil alternating with three rows of isabgol, (3:1 isabgol-lentil intercropping system) reduced LAI, the least. Leaf senescence started earlier in the sole isabgol than in the intercropped. The LAI corresponds to 1.36, 1.25, 1.17 and 0.96 at 100 DAP in the sole, 3:1 isabgol-lentil intercropping system, 1:1 isabgol-lentil intercropping system and 1:3 isabgol-lentil intercropping system, respectively.

Fig. 1 shows that the dry weight of isabgol expressed in terms of CGR was affected more than LAI due to shading effect in intercropping systems. Averaged across all proportions there was 51.4 and 31.2% reduction in CGR and LAI in intercropped isabgol in association with lentil over sole isabgol.

Yield and Yield Attributes: Sole isabgol recorded least plant height (16.9 cm), leaf number per plant (37.0), tiller number per plant (3.8), spike length (1.9 cm), spike number per plant (6.7), grain number per spike (71.7) and 1000-grain weight (1.4 g). In most cases these were significantly (*P*#0.05) increased in association with lentil (Table 2). The magnitude of increasing in these attributes was more when isabgol plants grown at proportion of one row of isabgol alternating with three rows of lentil. The greatest leaves number per plant (41.3), tiller numbers per plant (4.2), spike length (2.1 cm), spike number per plant (7.0), grain numbers per spike (77.2) and 1000-grain weight (1.5 g) were recorded in isabgol plants in association with lentil at 1:1 isabgol-lentil intercropping system, while the greatest plant height (18.0 cm) was observed in 3:1 isabgol-lentil intercropping system. Isabgol in association with lentil at proportion of 1:1 had most impact on yield attributes.

The highest biological and grain yields (712 and 281 kg ha^{-1}, respectively for biological and grain yield) were obtained in sole isabgol. Grain yield and biological yield of isabgol intercropped with lentil was reduced due to suppressive effect of lentil. Significant (*P*#0.05)

Table 3: Effects of cropping systems and irrigation interval regimes on biological and grain yield of isabgol and lentil, partial LER and total LER

	Isabgol		Lentil		Partial LER		
	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Biological yield (kg ha^{-1})	Grain yield (kg ha^{-1})	Isabgol	Lentil	
Cropping systems							
Sole lentil	-	-	2680a	1096a	-	1.00a	1.00c
1:3 isabgol-lentil	235d*	93d	2136b	846b	0.33d	0.77b	1.10b
1:1 isabgol-lentil	481c	191c	1678c	644c	0.68c	0.59c	1.27a
3:1 isabgol-lentil	589b	230b	785d	318d	0.82b	0.29d	1.11b
Sole isabgol	712a	281a	-	-	1.00a	-	1.00c
Irrigation interval regimes							
4 days	573a	235a	2002a	819a	0.54b	0.54a	1.08b
7 days	501b	193b	1812b	721b	0.57ab	0.52a	1.09ab
14 days	439c	168c	1646c	638c	0.59a	0.53a	1.12a

* Values followed by the same letter within the same columns do not differ significantly at *P* = 5% according to DMRT

Table 4: Effects of cropping systems and irrigation interval regimes on total N concentration of isabgol and lentil and N uptake from soil

	Total N concentration (gka^{-1})				
	Isabgol		Lentil		
	Total N concentration (g ka^{-1})	N uptake from soil (kg ha^{-1})	Total N concentration (g ka^{-1})	N uptake from soil (kgha^{-1})	
Cropping systems					
Sole lentil	-	-	32ab	85.8a	85.8a
1:3 isabgol-lentil	25a*	5.9d	34a	72.6b	78.5b
1:1 isabgol-lentil	22b	10.6c	33a	55.4c	66.0c
3:1 isabgol-lentil	22b	13.0b	31b	24.3d	37.3d
Sole isabgol	19c	17.8a	-	-	17.8e
Irrigation interval regimes					
4 days	24a	13.8a	35a	70.1a	83.8a
7 days	22b	11.0b	32b	58.0b	69.0b
14 days	20c	8.8c	31b	51.0c	59.8c

* Values followed by the same letter within the same columns do not differ significantly at *P* = 5% according to DMRT

reduction in grain yield and biological yield of isabgol in intercropping were recorded with decreasing isabgol proportion from 75 to 25%. Cultivation of isabgol at proportions of 3:1 isabgol-lentil intercropping system, 1:1 isabgol-lentil intercropping system and 1:3 isabgol-lentil intercropping system produced 51, 90 and 188 kg ha^{-1}, respectively, less grain yield of isabgol than the respective yields in monoculture.

Most yield attributes of isabgol were significantly ($P \leq 0.05$) lower as a result of drought (Table 2) caused by increasing irrigation interval. Biological yield of isabgol was significantly ($P \leq 0.05$) lower with increasing irrigation interval from 4- to 7 days and from 7- to 14-days. The difference between biological yield of intercropped isabgol grown under 4, 7 and 14-days irrigation interval was significant (Table 2).

Increasing irrigation interval gave lower grain yields of isabgol (235 kgha^{-1} at 4-days irrigation interval compared with 193 and 168 kgha^{-1} for 7 and 14 days irrigation interval, respectively). Biological and grain yield loss due to drought was significantly ($P \leq 0.05$) higher in mono crops than that of grown under intercropping systems. There was significant irrigation interval by cropping system interaction on all measured yield attributes except plant height and 1000-grain weight.

Yield Advantage of Intercropping: Yield advantage in terms of Land Equivalent Ratio (LER) for all the intercropping treatments was greater than unity. The highest LER value was recorded under 1:1 isabgol-lentil intercropping system (1.27) followed by 3:1 isabgol-lentil intercropping system (1.11) and the lowest obtained in 1:3 isabgol-lentil intercropping system with a value of 1.10. The high LER value in 1:1 isabgol-lentil intercropping system was due to high partial LER values of both isabgol and lentil in this system. Partial LER values of isabgol varied much more compared to lentil at different cropping system. Partial LER values of isabgol varied from 0.33 to 0.82, whereas partial LER values for lentil were more stable (0.29 to 0.77).

Differences among irrigation regimes were significant (P#0.05) for LER, grain yield were lower but LER were higher for 14-days irrigation interval than for 7- and 4-days.

Total N Concentration of Isabgol and Lentil: Total N concentration of isabgol and lentil in response to cropping system and irrigation regimes are given in Table 4. The concentration of N in intercropped isabgol were significantly (P#0.05) higher than in monocrop isabgol, but there was no difference in N concentration between lentil plants in monocropping and intercropping systems. Compared with sole isabgol, the N concentration of intercropped isabgol was increased by 31.6, 15.8 and 15.7% in 1:3 isabgol-lentil, 1:1 isabgol-lentil and 3:1 isabgol-lentil, respectively.

Total N concentration of isabgol and lentil were significantly (P#0.05) lower as a result of postponing irrigation from 4 to 7 or 14 days. Irrigation regimes by cropping system interaction effect for N concentration were significant (P#0.05) in both isabgol and lentil.

DISCUSSION

Although grain and biological yields of the component crops in association were low as compared to their respective sole crop yields, higher LER in intercropping treatments indicated yield advantage over monocropping due to better land utilization. Mean values of LER ranging from 1.10 to 1.27 were obtained from different proportion of isabgol and lentil intercropping system. This means the sole culture of each crop requires 10 to 27% more land than the intercropping system to produce equal yields indicating greater land-use efficiency of intercrops than sole crops. Successful intercropping occurs when each species occupies and accesses resources from different ecological niches while minimizing competitive interactions [19]. For example, isabgol and lentil may have different peak times for water and nutrient uptake or their leaf or their leaf arrangements may allow for greater light utilization. In contrast, if a particular combination of species and or varieties occupy similar ecological niches, it is unlikely that intercrop yield benefits will be observed. Similar findings were reported for intercropping of soybean-pigeonpea [20]; switchgrass-milkvetch [21]; Leek-Celery [14]; wheat-chickpea [22] scarlet eggplant-cowpea [12]; wheat-white clover [23].

These effects of intercropping on grain and biological yields of isabgol were prominent on CGR and LAI. Intercrops limited the light reaching the isabgol canopy and thereby reducing photosynthesis. This restricted photosynthesis was further shown by lower CGR and LAI. These results are in line with Bandel *et al.* [24], who reported that the association with a species in intercropping system reduces plant growth. As expected, individual plant growth and also yield attributed which calculated based on single plant of both isabgol and lentil was highest at lowest population of plant in association and increased with increasing plant population.

Plant growth, grain and biological yields of both component crops were decreased by drought induced by increasing irrigation interval. Deleterious effects of drought on plant growth are well known and have been documented for number of plant species [17, 25].

Under 14-days irrigation interval regime the LER value was higher in the intercropping systems than monocropping, but there was no difference in the LER value between the monocrop and intercrop treatments under 4-days irrigation interval regime. It means, intercropping protects plant growth and as a result grain production from the effects of drought. Different plant species growing together might be expected to exploit the edaphic and aerial resources available in a different manner to each other.

It is possible that there was an increase in the soil N made available by the leguminous lentil species and this could be the reason why there was an increase in total N concentration of isabgol plant with intercropping with lentil. Legumes grown with non-legume crops may supply a substantial amount of the N needed by the non-legume crops. By calculating the amount of N taken up into the plants and from the mass of biomass produced and concentration of total N in plants, it can be seen that total N uptake into the sole lentil, 1:3 isabgol-lentil, 1:1 isabgol-lentil, 3:1 isabgol-lentil and sole isabgol was 85.8, 78.5, 66.0, 37.3 and 17.8 kg ha^{-1}, respectively. As there were only 75 to 25% land area occupation by the isabgol itself in the intercropping treatments compared with 100% in the monocrop treatment, it can be seen that total N uptake by the isabgol per land area actually occupied by the isabgol itself was considerably greater in the intercropping treatment. This may be explained by additional N in the soil fixed by the legume crop being transferred to the isabgol, although it is possible that other factor that improved isabgol growth enabled the isabgol plants to acquire their own N more efficiently.

As reported by Gunes *et al.* [11] and Marschner [26], decreasing water availability under drought stress generally results in reduced total nutrient uptake and frequently leads to reduced concentrations of mineral nutrients in crop plants. In agreement with this, drought

caused decreases in N concentration in isabgol. However, there was no cropping system by irrigation interval regimes, so that intercropping did not protect the plant from the reduction in nutrient concentration resulting from drought stress.

CONCLUSION

In conclusion, the current study showed that the inclusion of lentil in isabgol inhibited the normal growth, CGR and LAI in isabgol, resulting in decreased grain and biomass yield. However, growing lentil between isabgol rows could produce additional grain legume lentil yield in the intercropping system. At this study Intercropping of isabgol and lentil reduced the impact of drought on plant productivity. The increase observed in N concentration in isabgol plants at intercropping system is indicative of an improved N availability to isabgol plants. Moreover, intercropping brings other benefits such as reduced risks of single crop failure, diversified farm incomes, increased soil organic carbon content and reduced herbicides input. This study showed that intercropping of grain legume in isabgol could be implemented as an economic efficiently system of production medicinal plants under drought conditions.

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